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Air Quality Formation Factors of Urban Areas (with the Example of the Odessa City)

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Abstract. Urban areas are characterized by a concentration of the technogenic sources of pollution, and their functioning is a major factor in the formation of the air basin quality. Odessa is characterized by the high levels of the air basin pollution, a significant dominance of the mobile sources of the air basin pollution, an insufficient landscaping level and public use green areas in some city districts, an unsatisfactory condition of the city trees and a presence of the unwanted species (sources of poplar fluff) and weeds (ragweed etc.). The level of a technogenic load on the Odessa air basin from the stationary sources is much higher than the one in the region. Reduction of the air basin pollution is possible due to redistribution and regulation of the traffic flows, increasing motor transport environmental friendliness, reorientation of the industrial production to the suburban territories, further improvement of an ambient air monitoring system, increasing the greenery share, stimulating the energy efficiency and reducing a resource consumption in the production and housing services, attracting the use of the alternative energy sources.

Key words: air basin, urban areas, pollution, a technogenic load.

Introduction

Urban areas are detached sources of pollution and are one of the main factors of environmental changes. The combination of ideas about the urban areas condition and quality is based on studying its most vulnerable natural part, whose components are indicators of an anthropogenic impact on the urban environment. The authors of the work (Albert, 2018) note that exposure to air pollution is the fifth ranking human health risk factor. According to WHO, more than 80% of urban areas are characterized by high levels of pollution. For low and middle income countries that figure rockets to 98% (Notman, 2017).

Odessa is not only a large multifunctional city in the south of Ukraine, but it is also a territory that causes an adverse environmental situation. Air basin pollution is a priority area among the current environmental problems of Odessa (Safranov et al., 2007; Glushkov et al., 2017). According to the Central Geophysical Observatory named after B. Sreznevsky (2018) (CGO, 2019), by the value of complex *API* Odessa belongs to the five most polluted cities in Ukraine.

The aim of the work is to evaluate and analyze a level of air pollution in Odessa to substantiate the measures to improve the air basin condition. To accomplish this, we must

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complete the following tasks: summarize the long-term data of the air pollution indicators in Odessa; analyze the main factors that cause a current condition of the Odessa air basin.

Materials and Methods

Assessment and analysis of an air pollution level in Odessa were performed over the multi-year period 2003 – 2018. The materials of the Black Sea and Azov Sea Hydrometeorological Center from monitoring the air quality of the city at the network of the constant observation points, as well as the Regional reports on the state of the environment and Ecological passports of the Odessa region were used for the evaluation. The data included the results of the observations at a network of 8 stationary observation points in the city. The observations of the individual impurities content in the air at this time are carried out according to the short or full programs, which provide air sampling daily 2 (07.00 and 19.00) - 4 (01.00, 07.00, 13.00 and 19.00) times a day, followed by the analysis in a chemical laboratory. At the same time, certain meteorological parameters, which can be used as the influencing factors in predicting the air pollution in the future are determined.

To assess a level of air pollution, a method of estimation based on calculating *API* and complex *API* (*CAPI*) was used. *API* is calculated as a separate admixture by the formula (Bezuglaya, 1986):

$$API = \left(\frac{\bar{q}}{MPC_{da}}\right)C_i \quad (1)$$

where MPC_{da} is daily average maximum permissible concentration; *Ci* is a constant that acquires values of 1,7; 1,3; 1,0; 0,9 respectively for 1; 2; 3; 4th grade of a substance harm and allows you to bring a degree of harmfulness of the *i*-th substance to a degree of dioxide sulfur harm.

According to the methodology if *API* ≤ 1 a quality of air on the content of a separate pollutant meets sanitary and hygiene requirements.

Complex *API* is a quantitative description of an air pollution level formed by *n* substances which are present in the atmosphere of the city. *CAPI* is calculated by the formula (Bezuglaya, 1986):

$$CAPI = \sum_{i=1}^{n} API_i \quad (2)$$

For the integral estimation of an air pollution level with the help of *CAPI*, one can use the values of individual air pollution indexes of the 5 pollutants for which these values are the greatest. The equation is (Bezuglaya, 1986):

$$I_5 = \sum_{i=1}^{5} API_i \quad (3)$$

The I_5 value of less than 2.5 corresponds to a clean atmosphere; from 2,5 to 7,5 – slightly polluted; from 7.6 to 12.5 – contaminated; from 12.6 to 22.5 – heavily polluted; from 22,6 to 52,5 – highly polluted; more than 52.5 – extremely polluted atmosphere (Bezuglaya, 1986).

Results and Discussion

Analysis of the initial information showed that in Odessa, observations are generally made on the content of 11 pollutants. We used information about the content of 7 pollutants, which were constantly present in the information sources. These are substances such as dust (total suspended particles), soot, carbon monoxide, nitrogen dioxide, phenol, hydrogen fluoride and formaldehyde. It should also be noted that the content of the other 4 pollutants is much lower than the *MPC* and does not significantly affect the formation of a general level of atmospheric pollution in the city.

Fig. 1 presents the data on the dynamics of changing the average annual pollutant concentrations in the air of Odessa. As it can be seen, the concentrations of almost all substances exceed the value of the daily average maximum permissible concentrations (MPC_{da}) by an average of 1.5 - 2 times. The maximum concentrations are indicated by the content of formaldehyde (3.3 MPC_{da} and more). The content of phenol, soot, hydrogen fluoride and formaldehyde tends to decrease in concentrations, a slight increase is observed in the carbon monoxide content.

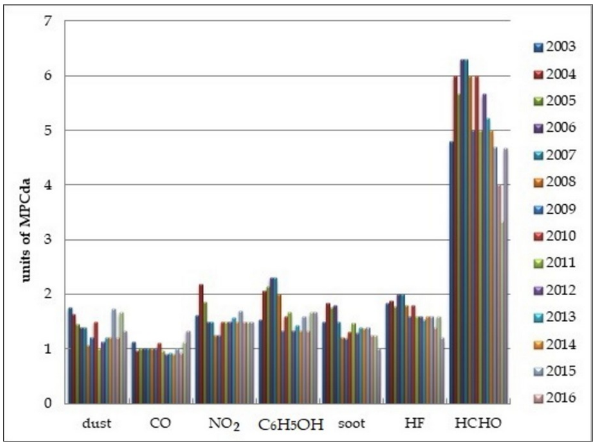

Fig. 1. Dynamics of changing the average annual pollutants concentrations in the air of Odessa in 2003 – 2018.

Fig. 2 shows the results of the *CAPI* and I_5 calculations. It should be noted that in the period 2003 – 2017, the content of 4 pollutants, namely nitrogen dioxide, phenol, hydrogen fluoride and formaldehyde, was constantly taken into account while calculating I_5. The fifth indicator was the content of soot (most often) or dust. In 2018, I_5 was calculated on the content of dust, carbon monoxide, nitrogen dioxide, phenol and formaldehyde.

Fig. 2 shows that during the study period a general tendency of decreasing the level of air pollution in Odessa is manifested. Highs were recorded in 2004, 2006 – 2007 by increasing the formaldehyde content.

According to the value of I_5, a level of air pollution in Odessa can be classified as: 2003 – 2015 – "heavily polluted"; 2016 – 2017 – "contaminated"; 2018 – "heavily polluted".

It should be noted that the obtained results do not correspond to the data from the results of monitoring at the mobile posts in 2009 – 2011. A comparative analysis of the level of air pollution according to the data of stationary and mobile points was performed in the work (Chugai et al., 2012). Thus, according to the mobile observations, the content of individual pollutants was somewhat lower, but the data was matched, i.e. the order of the concentrations was uniform.

The principle of calculating a technogenic load module (M_T), which is defined as a sum of weight units of all types of wastes (solid, liquid, gaseous) from the industrial, agricultural and municipal objects for a time interval of 1 year to the area of the administrative district or region within which these objects are situated was applied to estimate a technogenic load on the air basin, measured in thousands of t/km^2 per year (Adamenko & Rudko, 1997). Based on the principle of M_T determination, the assessment of the anthropogenic load level on the air basin was performed on the basis of calculating an anthropogenic load module on the air basin (M_{AB}), which is defined as the amount of pollutants emissions into the air in thousands of t/km^2 per year.

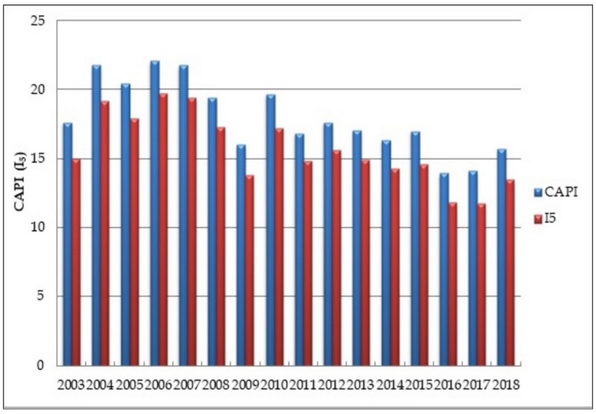

Fig. 2. The value of *CAPI* and I_5 in Odessa in 2003 – 2018.

The estimation of an anthropogenic load on the air basin of the Odessa region and Odessa was performed according to the data of the pollutants emissions from the stationary and mobile sources given in the regional reports by Odessa Regional State Administration (DENR-ORSA, 2010-2019). It should be noted that the mobile sources are the predominant sources of emissions for both Odessa and the Odessa region. Fig. 3 shows the results of calculating the M_{AB} indicator for the Odessa region.

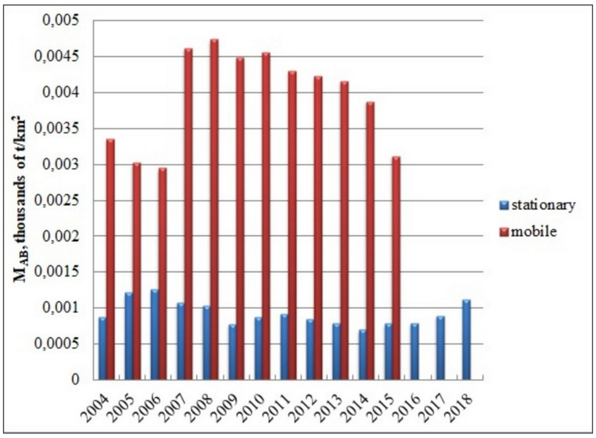

Fig. 3. The value of the M_{AB} indicator for the Odessa region.

Fig. 3 also shows that the level of loading from the mobile sources is significantly higher than the one from the stationary sources. For the mobile sources in the region a sharp increase in the M_{AB} index in 2007 with a further decrease was determined. Also, as of 2016, the official data lack the information on the emissions from the mobile sources and it complicates the analysis considerably. For the stationary sources, a level of loading during the study period was slightly varying. In 2018 it is in line with 2005 – 2007.

A level of technogenic load on the Odessa air basin from the stationary sources is much higher than the one in the region (see Fig. 4). This is quite natural, since the amount of emissions in the city of Odessa in different years was from 30 to 50 % in the region as a whole. There was a downward tendency in the load from 2007 to 2017, however, in 2018, the M_{AB} indicator increased significantly. In our opinion, this is a consequence, first of all, of non-compliance with the requirements for the limits of pollutants emission into the atmosphere.

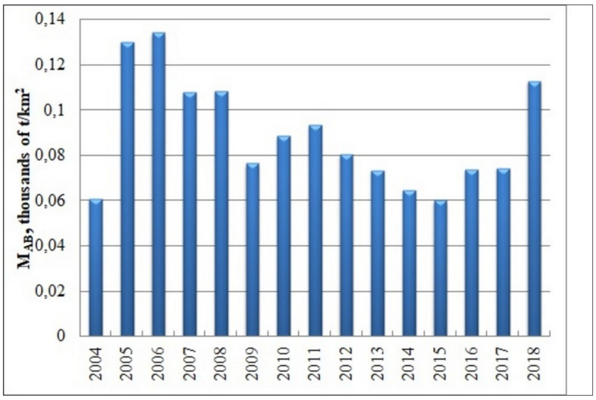

Fig. 4. The value of the M_{AB} indicator for Odessa (stationary sources).

The network of 8 stationary points for the air quality covers mainly the central and northern parts of Odessa (Fig. 5), and 23 route posts are located throughout the city. But most of the stationary posts are located in the areas which are heavily influenced by the stationary and mobile sources of the air pollution, and therefore the mean values of *API* do not give a real idea of the difference between technogenically-loaded and rural-recreational zones (respectively 25 % and 75 % of the city area territory). The most stationary sites are located in the residential area, and the main industrial pollution sources are located in the northwestern part of the city. Since the northwestern winds dominate, it negatively affects the state of the air basin at the locations of the stationary posts. Therefore, a network of the stationary air quality stations in Odessa should be updated and optimized.

Most of the stationary posts for air pollution monitoring are located on the windward side, and this is negatively reflected in the indicators of the air condition in the historic and residential parts of the city.

A level of environmental safety of the stationary pollution sources can be increased by improving air protection measures and technological processes, streamlining a configuration of the sanitary protection zones, etc., but a dominance of the mobile air pollution sources complicates the situation, since these measures should be applied to a large number of mobile pollution sources (for example, in 2013, 84.1 % of all the pollutants entered the city's air basin from the road, rail, air and water transport, as well as from the manufacturing equipment). Measures to reduce air pollution by redistributing and regulating traffic flows, as well as improving the environmental performance of vehicles are inefficient. This is due to the fact that a state of Ukrainian cars is poor (27 % of cars are over 30 years and 47 % of cars are between 10 and 30 years).

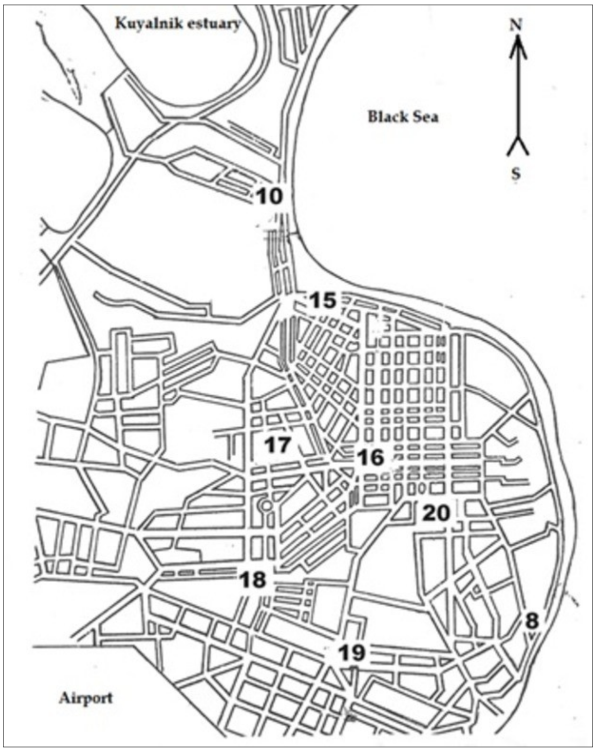

Fig. 5. Locations of the stationary points in Odessa.

In addition, the list of the pollutants monitored in Odessa does not meet the urgent needs, namely: there is no distribution of solids (*PM*) by a diameter of 10 µm and less (PM_{10}) and a diameter of 2.5 µm and less ($PM_{2.5}$). A number of harmful pollutants (*As*, *Cd*, *Hg*, *Ni*, polycyclic aromatic hydrocarbons, volatile organic compounds) are ignored (Announmous, 2020). In the EU, the monitoring program is based on the threshold levels, the excess of which determines a need for some type of monitoring. This makes it possible not to measure a large number of substances, focusing instead on the key pollutants. The methods of measuring pollutants concentrations that are currently being monitored in Odessa also require improvements.

In August 2019, Ukraine approved a new "Procedure for State Monitoring in the Field of Air Protection" (Ukranian Ministry, 2019). This Procedure is a step towards the implementation of the model of air monitoring in EU countries. Unlike, for example, according to this document it is planned to isolate $PM_{2.5}$ and PM_{10} from the monitoring system operating in Ukraine.

Continuous monitoring of meteorological parameters and individual indicators of the air quality is carried out at the stationary post of Odessa State Environmental University (OSENU) since May 2019 using the Air Quality Transmitter AQT420 of Vaisala Oyj (Republic of Finland), which was acquired within the Erasmus International Project in 2018 + 561975-EPP-1-2015-1-FI-EPPKA2-CBHE-JP (ECOIMPACT) (e-impact.net). The list of pollutants determined by this apparatus includes nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone and particulate matter.

We compared the observations of a content of the individual pollutants at OSENU with the long-term observations in the city as a whole. Note that according to WHO recommendations (WHO, 2006), the PM_{10} content is used as a primary indicator of the suspended substances content. The nitrogen dioxide content and the carbon monoxide content were also evaluated. Fig. 6 shows the *API* values for these substances in the summer-autumn period according to the observations at the OSENU post.

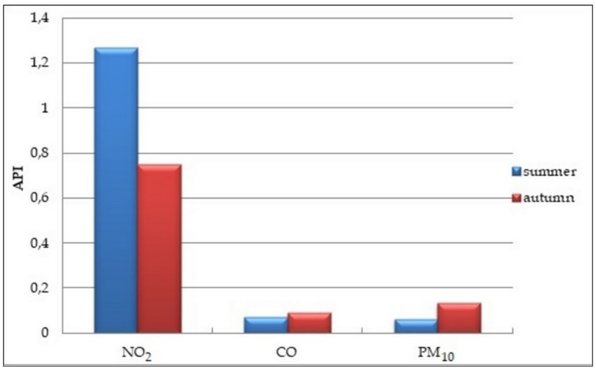

Fig. 6. The individual pollutants *API* values according to the observations at the OSENU post (2019).

The analysis of Fig. 6 and Fig. 1 shows that the nitrogen dioxide content generally corresponds to the average long-term values in the city as a whole. The carbon monoxide content is two orders of magnitude lower, according to the observations at a network of posts in the city, the PM_{10} content is one order of magnitude lower than the dust concentrations. There are no industrial sources of pollutant emissions near the observation point at OSENU, the most important sources are road transport. The territory OSENU is located in close proximity to the Black Sea coasts.

In order to obtain reliable estimates of the air quality, there is an urgent need to align the current monitoring system in Ukraine to the requirements of the new "State Monitoring Procedure in the field of air protection" (Ukranian Ministry, 2019) and to conduct the observations with a single metrological and methodological support.

An important factor influencing the air quality is a state of greenery. The city's green area is 742 hectares, which is in terms of one resident is 7.4 m^2/person and is 61.7 % for the city. If in the center of the city there are about 4 m^2 of greenery on average per person (at the norm of 12 m^2), then in the large residential areas there is no more than 1 m^2 of plantations per capita. In some areas the number of green spaces per inhabitant is only 17 % of the national standard. It should be noted that WHO is proposing the even higher figure – 50 m^2 per urban dweller – as a necessary norm for ensuring public health (Russo & Cirella, 2018).

The area of green space in recent years has decreased by about 25 %, and it is very important to expand a recreational zone of the city by creating the "Odessa Green Belt" (Halin, 2020), which implies a creation of a continuous ring of parks, squares and green corridors around the historic city center. In this ring it is proposed to create the conditions for a convenient movement of pedestrians and cyclists, as well as to place several intermodal electric transport stop complexes (a city train, a tram, a monorail). The conditions created here and a new transport infrastructure will attract investors' interest to construct residential complexes on its border. The areas around the railway are the most promising for creating a natural frame. The railway branch enters the city from the north and skirts its historic part. At present it is a strip of depressed territories: idle industrial enterprises, warehouses, a low-rise residential sector. The green space will help to clean the city's air basin from the harmful gas impurities, to retain dust particles, to curb wind gusts, to absorb noise and to enrich the air with oxygen.

It should be noted that less than 10 species of native shrubs are involved in the species composition of the city's flora, but in the landscaping of the city about 800 species and forms imported from other countries and continents, which are decorative, and at the same time well tolerate the air pollution and paving the streets and also are capable of catching dust and harmful fumes, are usually used. Since female poplar individuals produce fluff, it is advisable to use only male specimens in the city's landscaping. Among about 900 species of city's grassland, over one third are weeds.

During flowering a part of them is an allergen (for example, *Ambrosia artemisiifolia*). Therefore, for the accumulation of harmful impurities, it is proposed to plant also the resistant varieties of shrubs. The work (Vasilieva et al., 1998) substantiates a need to treat the plants carefully, to select their correct assortment, as well as to care of them properly. Based on the study of the authors (Bonetsky, 1998), in order to neutralize a number of harmful impurities in the urban air, it is recommended to plant such shrubs as horse chestnut, nanking cherry, American sycamore, *Platycladus orientalis*, and atlas cedar, as well as essential oil plants-terpenoproducers.

In Odessa, an increase in air temperature (maximum, minimum, average), a change in the nature of precipitation, a change in the duration of the growing season, the shift of climatic seasons, etc., were recorded. In addition, the city's population structure, a poor infrastructure, an inadequate funding, high levels of air pollution, etc. increase the city's vulnerability to the potential negative effects of climate change significantly (Shevchenko et al., 2014). Since the green areas are the most vulnerable ones in the city, when developing a city adaptation plan a significant part of the measures should be aimed at reducing the vulnerability of urban greening. One of the ways of the Odessa's adaptation to the climate changes (reducing the effect of a climate urbanization) is to increase the area of green space.

Conclusions

As a result of the conducted research we can draw the following conclusions:

1) The concentrations of almost all pollutants exceed the average daily *MPC* by 1.5 – 2 times; the content of phenol, soot, hydrogen fluoride and formaldehyde tends to decrease in the concentrations, the carbon monoxide content is slightly increasing.

2) By the I_5 value , the air pollution level in Odessa can be classified as: 2003 – 2015 – "heavily polluted"; 2016 – 2017 – "contaminated"; 2018 – "heavily polluted".

3) The level of a technogenic load on the Odessa air basin from the constant sources is much higher than the one in the region; there was a downward trend in loading from 2007 to 2017, however, in 2018, the M_{AB} indicator increased significantly, which is a consequence of non-compliance with the requirements for the air emission limits.

4) A list of pollutants monitored in Odessa does not meet the urgent needs, namely: there is no distribution of PM_{10} and $PM_{2.5}$; a number of harmful pollutants are remained unaddressed; the methods for measuring the pollutants concentrations need to be improved.

5) The comparison of these observations data according the individual pollutants content at the OSENU posts with the data of the long-term observations in the city showed that the NO_2 content corresponds to the average multiple-year observations in the city as a whole, the *CO* content is two orders of magnitude lower than the observations data at a network of posts in the city, the PM_{10} content is one order of magnitude lower than dust concentrations; a network of the stationary observation points for air quality in Odessa should be updated and optimized.

6) A network of 8 stationary points covers mainly the central and northern parts of Odessa, and 23 route posts are located throughout the city. But most of the points are located in the areas that are heavily influenced by the stationary and mobile sources of air pollution, and therefore the mean *API* values do not give a real idea of the difference between the technogenically-loaded and the rural-recreational zones (25 % and 75 % of urban area).

7) The level of environmental safety of the stationary sources of pollution can be increased by improving the air protection measures and technological processes, streamlining the configuration of the sanitary protection zones, etc., but a dominance of the mobile sources of the air basin pollution complicates the situation, since these measures should be applied to a large number of poor state vehicles.

8) An important factor influencing the air quality is a state of greenery. The city's green area is 742 hectares, which is in terms of one resident is 7.4 m^2/person (at the state standard of 12 m^2/person for the cities of the Odessa level and also the WHO standard of 50 m^2 for one urban resident).

9) The green area has decreased by about 25 % in recent years that is why it is very important to expand a recreational zone of the city by creating a "Green Belt of Odessa" (a continuous ring of parks, squares and green corridors).

10) In order to neutralize a number of harmful impurities in the urban air, it is recommended to plant shrubs such as horse chestnut, Nanking cherry, American sycamore, *Platycladus orientalis*, and atlas cedar, as well as essential oil plants-terpenoproducers.

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